FORMATION ENVIRONMENTAL

MEMORANDUM

TO: Dwight Leisle, PE, PMP, Port of Portland

CC: Herb Clough and Michael Pickering, Apex Companies, LLC

FROM: Mark Dunn Lewis, PhD and Emily Stinson, Formation Environmental, LLC

DATE: November 19, 2013

SUBJECT: Effects of Proposed Source Control Action on Ecological Risk: Swan Island Upland Facility, Operable Unit No. 2

Introduction

This analysis describes the implications that the proposed Source Control Action (SCA) for operable unit 2 (OU2) of the Swan Island Upland Facility (SIUF) have on baseline ecological risk from chemical contaminants in riverbank soil along the Willamette River.

The SCA was identified in the Source Control Alternatives Evaluation (SCAE) conducted by Apex Companies, LLC (Apex) (2012). The SCAE was prepared in response to a request by the Oregon Department of Environmental Quality (DEQ) to identify, evaluate, and control sources of contamination that may reach the Willamette River consistent with the DEQ-Environmental Protection Agency (EPA) Portland Harbor Joint Source Control Strategy (JSCS) (DEQ/EPA 2005). This work is being conducted under an agreement between the Port of Portland (Port) and DEQ – Voluntary Agreement for Remedial Investigation, Source Control Measures, and Feasibility Study (July 24, 2006).

As part of the investigations for the Voluntary Agreement, baseline exposure and risks for the riverbank area were evaluated and are described in the Level II Screening Ecological Risk Assessment for the site (Level II ERA) (Formation Environmental, LLC [Formation] 2012). The Level II ERA concluded that although metal concentrations exceeded screening-level values at some locations in the riverbank area, overall ecological function is not significantly affected and no active risk management is warranted for the site. DEQ disagreed with the methods and conclusions presented in the Level II ERA (DEQ 2013; Attachment A), and concluded that risk was unacceptable from elevated copper, lead, and zinc concentrations to plants, invertebrates, birds and mammals (Table 1).

The goal of the SCA is to control erosion of the riverbank at OU2 as a possible source of contamination to the Willamette River, but the SCA will also reduce the exposure of terrestrial biota to contaminants in soils of the riverbank area at OU2. The analysis reported below uses results of the Level II ERA and the DEQ comments to quantify the extent to which the SCA would reduce ecological risk within the OU2 riverbank area.

Proposed Source Control Action (SCA)

Details of the ecological and physical site descriptions can be found in Formation (2012) and Apex (2012), respectively. The recommended SCA for the OU2 riverbank soils consists of placing riprap armoring at two locations on the riverbank, then re-grading and re-vegetating the area to provide further stabilization (Apex 2012). The two locations to be covered contain elevated levels of copper, lead, and zinc; and the actions will reduce exposure of terrestrial biota to elevated concentrations of these metals. The location of the SCA and the effects on ecological risk are discussed in the following sections.

Effects of Proposed Source Control Action on Ecological Risk

Results of the Level II ERA and the DEQ comments were used as a basis for characterizing the extent to which ecological risk would be reduced as a result of the SCA. In their comments on the Level II ERA (DEQ 2013), DEQ provided some details on alternative assumptions about toxicity thresholds that were used to assess risk. However, they did not provide extensive details on how data were used or conclusions about risk at specific locations on the riverbank. The Port disagrees with some aspects of DEQ's analyses and conclusions about risk. In some cases, the differences in methods and interpretation could affect the conclusions about whether the SCA will result in acceptable ecological risk at the site.

The differences in interpretation focus mainly on (1) consistency of ecological benchmark values (EBVs) with Oregon rules for acceptable risk levels (ARLs), and (2) the potential effects on ecological function of plant and invertebrate populations. In addition, guidance for the generic DEQ Level II SLVs and the EPA EcoSSLs explicitly states that these values are not intended to represent cleanup levels for risk management actions without more site-specific analysis (DEQ 2001, EPA 2005). The analysis presented below includes more site-specific context for risk analysis assuming the SCAs are implemented. Therefore, the analyses can be used to help determine whether additional actions beyond the SCAs are necessary.

The following evaluates the baseline assumptions used by DEQ, provides analyses and interpretation regarding the effect of the SCA on risk at the site, and provides conclusions on whether the residual risk is within acceptable ranges based on Oregon rules. The analyses are presented for the three metals, with risk descriptions provided for each receptor group that DEQ identified as having unacceptable risk.

Copper

DEQ characterized risk from copper as unacceptable for all four receptor groups (Table 1). The effect of the SCA on risk from copper on each of the receptor groups is described below.

Plants – DEQ based its risk characterization on exceedence of screening levels at individual locations in the riverbank area (Figure 1). The screening level values (SLVs) that DEQ directed the Port to use in the Level II ERA are different from the SLVs published by DEQ (2001). The source of the values is the EPA Ecological Soil Screening Levels (EcoSSLs) for copper (EPA 2007). The EcoSSL for exposure of plants to copper is 70 mg/kg, which is the geometric mean of toxicity endpoints from six studies selected by EPA. The endpoints from the studies used in the EcoSSL are (1) the maximum allowable toxicant concentration (MATC) and (2) the concentrations that affect 10 percent of the test populations (i.e., EC10) (EPA 2007).

The soil conditions of the six studies selected for the EcoSSL calculation vary, including a range of soil pH from 4.4 to 6.4. The toxicity of copper to plants is highly dependent upon pH, especially for pH between about 5 and 7 (Suave et al. 1998). The studies cited in the EcoSSL document strongly reflect this. The geometric mean of endpoints from the studies from soils with pH>6 (range 6 to 6.4) is 160 mg/kg (range 141 to 251), whereas the geometric mean for studies with soil pH less than 6 (range 4.4-5.5) is 31 mg/kg (range 16 to 58).

No data on soil pH are available from the SIUF study area. However, soils with pH below 6 are not expected in this environment because the riverbank is constructed mainly of gravel and sand fill materials that are highly mixed and oxidized, and not expected to have acid-generating capacity. Therefore, it may be more appropriate to use a soil toxicity threshold that is more applicable to the soil conditions expected at the site. Five of the 23 surface locations analyzed for copper have concentrations that exceed 160 mg/kg. Three of these locations (RB9a, RB9b, and RB10b), including the highest concentration observed, will be covered under the proposed SCA. RB-1 (composite) (271 mg/kg) and RB-13b (567 mg/kg) would remain uncovered. The sitewide average concentration after the SCA is 93 mg/kg, which corresponds to a hazard quotient of approximately 1.3 compared to the EcoSSL (70 mg/kg), but is substantially lower than the alternative 160 mg/kg toxicity value based on soil pH>6. None of the remaining sites exceeds the hot spot concentration for plants (700 mg/kg for the EcoSSL, or 1,600 mg/kg for the adjusted screening level).

For non-threatened/endangered (T/E) species, the Oregon ARL has two elements: (1) a probability no greater than 0.1, that 20% or more of the local population experiences exposures greater than the Ecological Benchmark Value (EBV) for a given chemical ($P_{20\%}$); and (2) there are no other observed significant adverse effects on the health or viability of the local population (DEQ 2001). The EBV for the ARL analysis is defined as the LD50, or the exposure that results in about 50% mortality in the test population (DEQ 2001; OAR 340-122-115(6)). The probabilistic analysis was applied to plants using the OU2 soil samples as a basis for the exposure estimate and a plant population size of 100 individuals.

The EBVs included in the analysis were the 70 mg/kg EcoSSL cited by DEQ, and the 160 mg/kg EBV based on higher soil pH levels. Both EBVs are based on sublethal growth and

reproduction endpoints, which represent lower levels of effects than the LD50 endpoint specified for the Oregon ARL. The primary source of information for plant toxicity levels was the EcoSSL document which does not include LD50 endpoints for plants. The EBVs represent more protective endpoints than intended by the Oregon statute. Therefore, if $P_{20\%}$ for such sublethal LOAELs or NOAELs is less than 0.1, then risk is acceptable under the Oregon rules (unless other signs of significant adverse effects are observed).

Under baseline conditions (i.e., SCA not implemented), the $P_{20\%}$ for both of the sublethal EBVs exceeds 0.1 (Table 2). If the SCA is implemented, the $P_{20\%}$ exceeds 0.1 for the 70 mg/kg EBV, but not the 160 mg/kg EBV ($p < 0.001$) (Table 3). These results suggest that post-SCA conditions at the site likely represent acceptable risk for plants.

Invertebrates – DEQ based its risk characterization on locations that exceed 80 mg/kg, which is the EcoSSL for invertebrates (EPA 2007). Concentrations at eleven of the 23 surface sampling locations that were analyzed for copper exceed the EcoSSL (Figure 1). Four of these locations would be covered as a result of the SCA, including three of the highest concentrations onsite. Overall, the SCA will reduce the average concentration at the site from 228 mg/kg to 93 mg/kg (based on discrete samples), which corresponds to an HQ of 1.1 based on the EcoSSL; and none of the remaining site exceeds the hot spot concentration for invertebrates (800 mg/kg).

Since probabilistic exposure analysis for invertebrates would be based on the same data as for plants, and a very similar EBV (i.e., the SLV = 80 mg/kg), results for invertebrates are very similar. That is, risk of 20% of the population experiencing exposures that exceed EcoSSL-based EBVs exceeds 0.1. However, the projected concentrations remaining after the SCA are marginally above the EcoSSL. Since none of the studies on which the invertebrate EcoSSL were based included mortality endpoints, the residual risk is likely within acceptable ranges.

Birds – DEQ characterized risk from copper as unacceptable for birds based on probabilistic risk calculations that were modified as described in their comments from June 17, 2013. In a separate comment on the probabilistic assessment methods in the Level II ERA, DEQ determined that the population size (49 animals) used by the Port was too large, and should be 22 animals.

The EBV used by DEQ in the comments to judge whether risk was acceptable was not consistent with the ARL definition. Instead, DEQ used an EBV that was based on a LOAEL for a non-mortality endpoint, reproduction (12.1 mg/kg body weight (BW)/day)(EPA 2007). In the expanded Level II ERA (Formation 2012), a suitable LD50 was not identified for copper, but the Port identified an EBV that corresponds to a 40% mortality rate (68.4 mg/kg BW/day) which is much more consistent with the ARL definition than the reproduction LOAEL endpoint used by DEQ.

The probabilistic risk calculation for the American robin was repeated for baseline conditions at SIUF OU2 using the smaller population size (22 animals) recommended by DEQ. The methods and intake parameters are shown in Table 4, and the range of EBVs considered is presented in Table 5. The analysis was conducted for diets containing 100% invertebrate diets based on comments from DEQ on the draft ERA. The $P_{20\%}$ for the EBV identified by the Port (68.4 mg/kg

BW/day) was less than 0.1, which indicates that risk to birds is acceptable (below the ARL) under baseline conditions (Table 6).

The proposed SCA results in substantially lower risks. The effect of the SCA on risk to birds was assessed using the same probabilistic analysis, but replacing the baseline concentrations in soil for the locations to be covered (RB9a, RB9b, RB10a, and RB10b) with the background concentration for copper (34 mg/kg). The $P_{20\%}$ for the Port-recommended EBV cited above (68.4 mg/kg BW/day) was < 0.001, which is well below the threshold risk of 0.1 that is included in the definition of acceptable risk under Oregon law.

The $P_{20\%}$ for DEQ's LOAEL EBV of 12.1 mg/kg BW/day is 0.89 for the 100% invertebrate diet. This risk exceeds the 0.1 threshold level, but because the LOAEL EBV is not based on the LD50 concept, or even mortality endpoints, it is not consistent with the definition of acceptable risk specified in Oregon law.

Overall, the SCA would result in acceptable risk from copper to birds within the riverbank area of OU2.

Mammals – The conclusions and issues associated with the mammal risk analysis are similar to those for birds. DEQ determined that risk from copper to mammals was unacceptable based on the $P_{20\%}$ for an EBV of 9.3 mg/Kg BW/day. The exact source of the EBV was not specified by DEQ, but appears to be based on a LOAEL for reproduction and survival (Allcroft et al. 1961 as cited in EPA 2007). However, this value is lower than the geometric mean reported by EPA for growth and reproduction NOAELs (25 mg/kg BW/day) (EPA 2007). Furthermore, one study in the EcoSSL compilation is based on a shrew species that is very similar to the receptor used in the SIUF analysis. The mortality NOAEL from that study is 229 mg/kg BW/day, which is substantially higher than the LOAEL value cited by DEQ.

An acceptable LD50 for exposure of small mammals to copper was not available, so the Port used alternative EBV values in the probabilistic analysis. EBV values recommended by the Port were from the EPA EcoSSL compilation (EPA 2007). The recommended NOAEL was 25 mg/kg BW/day, which is the geomean of the growth and reproduction NOAELs calculated by EPA. The recommended LOAEL is 45.7 mg/kg BW/day (Grobner et al. 1986) which was the lowest LOAEL for growth that was higher than the recommended NOAEL. Both of these EBVs are based on non-mortality endpoints and are more conservative (protective) than mortality-based endpoints, and especially the LD50 on which the Oregon ARL rule is based.

The methods, intake parameters, and results of probabilistic modeling for mammals are shown in Tables 8 through 11. The population size of 29 animals was used, based on the population density reported for short-tailed shrews (12.9 animals/ hectare [ha]) identified in the US EPA Wildlife Exposure Factors Handbook (EPA 1993).

For baseline conditions, the $P_{20\%}$ for the DEQ LOAEL EBV was greater than 0.1 (Table 10). But, the $P_{20\%}$ for the LOAEL EBV cited by the Port (45.7 mg/kg BW/day) is approximately equal to 0.1 (Table 10). If the proposed SCA was implemented, the risks would be substantially lower, but the $P_{20\%}$ for DEQ's LOAEL-based EBV would still exceed 0.1 (Table 11). However, risks

would be acceptable (i.e., $P_{20\%} < 0.1$) if the Port alternative EBV were used (Table 11). In fact, an EBV as low as 17.25 mg/kg BW/day would result in a $p < 0.1$. Therefore, it's reasonable to conclude that the SCA results in acceptable risk within the riverbank area OU2.

Lead

Plants – DEQ states that "plant exposure is above risk levels", presumably based on concentrations above the 120 mg/kg screening level designated for lead. Three locations out of 36 total samples (composite and discrete) exceed the screening level. Of these, the two highest concentration locations (RB9a and RB10b) will be addressed under the SCA. The average concentration after the SCA is 48 mg/kg, and the concentration at the remaining location (RB4b) above the screening level is 170 mg/kg, which is well below the plant hot spot concentration of 1,200 mg/kg. As a result, risk from lead to plants would be within acceptable limits after SCA is implemented and no probabilistic analysis was completed.

Zinc

Plants – DEQ considers risk to plants from zinc as unacceptable, presumably due to soil concentrations that exceed the screening level. The screening level for zinc (160 mg/kg) is lower than the DEQ default background concentration of 180 mg/kg. Of the 23 total samples (composite and discrete) for which zinc data are available, eight have concentrations that are higher than background. Three of the eight (RB9a, RB9b, RB10b) will be addressed by the SCA. The average concentration after the SCA is 158 mg/kg, and none of the remaining locations have concentrations higher than the hot spot value for plants (1,600 mg/kg). Given the dispersed nature of these locations, risk to plant community function does not appear to be unacceptable.

Probabilistic analysis was not conducted for zinc because the Oregon background value is higher than the relevant risk screening levels (i.e., the SLV and EcoSSL).

Invertebrates – Since regional background exceeds the screening level for invertebrates (120 mg/kg), conclusions for invertebrates are the same as for plants. None of the sampling locations had zinc concentrations that exceed the invertebrate hot spot level of 1,200 mg/kg. As for plants, risk to invertebrates does not appear to be in an unacceptable range.

Conclusions

The SCA proposed by the Port for the SIUF OU2 riverbank to attenuate transport of COCs to the Willamette River also eliminates the potential for contact between ecological receptors and surface soils in the areas of the site with the highest copper concentrations, and elevated concentrations of lead and zinc. Since concentrations of the COCs are significantly elevated at a relatively few locations, covering the high concentration areas results in substantial sitewide reduction in the magnitude of exposure to ecological receptors.

Based on the analysis presented above, ecological risk at the site will be within acceptable ranges for birds and mammals after the SCA is implemented. The overall conclusions are based on interpretation of ARLs that the Port believes are consistent with Oregon statute [OAR 340-122-115(6)]. For probabilistic analysis, the interpretation focuses on the basis for the EBV. The Oregon statute [OAR 340-122-115(6)] explicitly identifies the LD50 or LC50 as the basis for the EBV used in ARL determinations. In their June 2013 comments, DEQ based conclusions of unacceptable risk on non-mortality endpoints, or based on mortality rates that are much lower than 50%. Use of such endpoints at a threshold for acceptable risk may not be consistent with the Oregon rules.

The conclusions for plants and invertebrates are similar. As a matter of policy, DEQ has determined that the invertebrate and plant SLVs should be applied on a point-by-point basis in the Level II screening. However, the Oregon rules explicitly identify populations of plants and animals in definition of ecological receptors (OAR 340-122-0115[22] and [40]). The DEQ guidance for Level I ERA explicitly discusses consideration of ecological importance and function of plants and invertebrates as a basis for site assessment (see Task 4, page I-3 in DEQ 2001). Therefore, the assessment of potential effects on the ecological function of plants and invertebrates is an appropriate endpoint on which to base cleanup decisions.

The precise level of COC exposure that allows protection of self-sustaining populations or habitat function may be difficult to determine, but can vary significantly depending upon the endpoint or function being considered, and site-specific conditions. Therefore, risk management interpretation should consider the potential variability, along with the physical and biological factors that may limit native habitat composition at a site. This may be especially relevant where cleanup requires significant disturbance of existing habitat.

The riverbanks at OU2 clearly support self-sustaining populations of plants of various species, indicating that phytotoxicity has not prevented natural vegetation of the area. The species composition may include invasive species such as Armenian (aka Himalayan) blackberry. But the presence of invasive species, or the absence of native species can be caused by many physical and biological factors and is not necessarily attributable to chemical toxicity from copper or other COCs. Therefore, it seems reasonable to conclude that the toxicological risk to the plant populations and ecological function is within acceptable ranges.

References

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Table 1. Summary of Oregon DEQ Conclusions on Ecological Risk

Swan Island OU2 Upland Facility Riverbank Soils

Analyte	Plants	Invertebrates	Birds	Mammals
Copper	U	U	U	U
Lead	U	A	Marginal U	A
Zinc	U	U	A	A

Notes:

U = DEQ judged risk to be unacceptable

A = DEQ judged risk to be acceptable

Based on DEQ (2013) review of SIUF OU2 Level II Screening Ecological Risk Assessment (Formation Environmental 2012).

DEQ (Oregon Department of Environmental Quality). 2012. Letter from David Lacey (DEQ) to Dwight Leisle (Port) re: DEQ review of "Level II Screening Ecological Risk Assessment OU2". July 17, 2013.

Formation (Formation Environmental, LLC). 2012. Level II Screening Ecological Risk Assessment (ERA) Portland Shipyard, Operable Unit 2 (OU2), Swan Island Upland Facility (SIUF). Prepared for Ash Creek Associates and the Port of Portland. September.

Table 2. Plant Population-level Probabilistic Risk Analyses for Copper: Baseline Conditions (discrete samples)

Swan Island OU2 Upland Facility

Analysis of probability of exposure exceeding Acceptable Risk Levels

CHEMICAL: **Copper** **Discrete samples only**

LOCATION	Concentration of Chemical in Soil		Dose of Chemical	
	Csoil (mg/kg)	ln(Csoil)	Dose (mg/kg BW/day)	ln(dose)
RB-9a	298.00	5.70	298.00	5.70
RB-12b	42.40	3.75	42.40	3.75
RB-11a	57.20	4.05	57.20	4.05
RB-14a	46.70	3.84	46.70	3.84
RB-13b	567.00	6.34	567.00	6.34
RB-9b	284.00	5.65	284.00	5.65
RB-10b	1640.00	7.40	1640.00	7.40
RB-11b	125.00	4.83	125.00	4.83
RB-10a	112.00	4.72	112.00	4.72
RB-13a	25.80	3.25	25.80	3.25
RB-15a	50.70	3.93	50.70	3.93
RB-15b	103.00	4.63	103.00	4.63
RB-8b	60.10	4.10	60.10	4.10
RB-8a	112.00	4.72	112.00	4.72
RB-12a	61.40	4.12	61.40	4.12
RB-14b	62.50	4.14	62.50	4.14

STATISTICS				
	mg/kg	ln	mg/kg BW/day	ln
Average	228.0	4.70	228.0	4.70
Standard Deviation	401.8	1.09	401.8	1.09
Distribution			log normal	

PROBABILISTIC ANALYSIS - log based calculations				
Number of individuals (n)		100		
EBV (mg/kg/day)	**ln(EBV)**	**Individual Probability of Exp>EBV (p)**	**Probability that more than 20% of the local population will experience Exp>EBV (b)**	**where b=1-BINOMDIST(#kills,#trials,prob of kill,cumulative)**
70	4.25	0.660	1.00	**Acceptable Risk Level (ARL) for non T/E Species: probability <0.1**
160	5.08	0.364	1.00	

Notes:

- Refer to Table 2 for description of all exposure parameters and intake/dose equations.
- Refer to Table 3 for description of all ecological benchmark values (EBV).
- All locations are within the riverbank area of Swan Island OU2 Upland Facility; analysis assumes even distribution across riverbank area
- Method Source: Oregon Department of Environmental Quality (DEQ). 2001. Guidance for Ecological Risk Assessment: Levels I, II, III, IV. Waste Management & Cleanup Division, Final. April 1998, updated December 2001.
- Acceptable risk level (ARL)[OAR 340-122-115(6)] for populations of ecological receptors is a 10% or less chance that 20% or more of the total local population would receive an exposure greater than the EBV.

Table 3. Plant Population-level Probabilistic Risk Analyses for Copper: Effect of Source Control Action (discrete samples)

Swan Island OU2 Upland Facility

Analysis of probability of exposure exceeding Acceptable Risk Levels

CHEMICAL: **Copper** **Discrete samples only**

LOCATION	Concentration of Chemical in Soil		Dose of Chemical	
	Csoil (mg/kg)	ln(Csoil)	Dose (mg/kg)	ln(dose)
RB-9a	34.00	3.53	34.00	3.53
RB-12b	42.40	3.75	42.40	3.75
RB-11a	57.20	4.05	57.20	4.05
RB-14a	46.70	3.84	46.70	3.84
RB-13b	567.00	6.34	567.00	6.34
RB-9b	34.00	3.53	34.00	3.53
RB-10b	34.00	3.53	34.00	3.53
RB-11b	125.00	4.83	125.00	4.83
RB-10a	34.00	3.53	34.00	3.53
RB-13a	25.80	3.25	25.80	3.25
RB-15a	50.70	3.93	50.70	3.93
RB-15b	103.00	4.63	103.00	4.63
RB-8b	60.10	4.10	60.10	4.10
RB-8a	112.00	4.72	112.00	4.72
RB-12a	61.40	4.12	61.40	4.12
RB-14b	62.50	4.14	62.50	4.14

STATISTICS				
	mg/kg	ln	mg/kg	ln
Average	90.6	4.11	90.6	4.11
Standard Deviation	130.5	0.75	130.5	0.75
Distribution			log normal	

PROBABILISTIC ANALYSIS - log based calculations				
Number of individuals (n)		100		
EBV (mg/kg)	**ln(EBV)**	**Individual Probability of Exp>EBV (p)**	**Probability that more than 20% of the local population will experience Exp>EBV (b)**	**where b=1-BINOMDIST(#kills,#trials,prob of kill,cumulative)**
80	4.38	0.360	1.00	**Acceptable Risk Level (ARL) for non T/E Species: probability <0.1**
160	5.08	0.100	0.0008	

Notes:

- Refer to Table 2 for description of all exposure parameters and intake/dose equations.
- Refer to Table 3 for description of all ecological benchmark values (EBV).
- All locations are within the riverbank area of Swan Island OU2 Upland Facility; analysis assumes even distribution across riverbank area.
- Yellow highlighted values are locations that will be covered as a result of the source control action; values were replaced with the background concentration for copper (34 mg/kg).
- Method Source: Oregon Department of Environmental Quality (DEQ). 2001. Guidance for Ecological Risk Assessment: Levels I, II, III, IV. Waste Management & Cleanup Division, Final. April 1998, updated December 2001.
- Acceptable risk level (ARL)[OAR 340-122-115(6)] for populations of ecological receptors is a 10% or less chance that 20% or more of the total local population would receive an exposure greater than the EBV.

Table 4. Approach for Calculation of Estimated Copper Intake for Modeled Receptor - Birds

Swan Island OU2 Upland Facility Riverbank Soils

Modeled Receptor: American Robin

Intake Equations:

Equation (a) - total CPEC intake

$$Intake_{total} = Intake_{food} + Intake_{water} + Intake_{soil}$$

Parameters - Equation (a):

Parameter	Description	Units	Value	Source/Notes
$Intake_{food}$	average daily intake from ingestion of prey items (vegetation and animal tissues).	mg/kg	calculated	See Equation (b)
$Intake_{soil}$	average daily intake from incidental ingestion of surface soil.	mg/kg	calculated	See Equation (c)
$Intake_{water}$	average daily intake from the ingestion of water.	mg/kg	0	No surface water at Upland Facility; water intake assumed to be 0.

Equation (b) - CPEC intake from food

$$Intake_{food} = AUF * \left(\sum_{i=1}^{N} B_{ij} * P_i * FIR \right)$$

Parameters - Equation (b):

Parameter	Description	Units	Value	Source/Notes
$Intake_{food}$	Intake for contaminant (j) in food	mg dw/kg bw-d	calculated	
AUF	Area use factor	unitless	1	Fraction of food derived from site; area use assumed to be 100%
FIR	Food intake rate	kg dw/kg bw-d	0.207	WDOE 2012 - food ingestion rate for American Robin
B_{ij}	Concentration of contaminant (j) in biota type (i) where $ln(B_{ij}) = Intercept_{ij}+Slope_{ij}*ln(Soil_j)$	mg/kg dw	$ln(B_{plants})=(0.394*ln(Soil_j))+0.668$	Plant concentration equations from Bechtel-Jacobs 1998 and invertebrate concentration equations from Sample et al. 1999, as recommended in EPA 2005
			$B_{inverts}=0.515*Soil_j$	
N	total number of ingested prey types	unitless	1	EPA 1993 - American robin diet
P_i	fraction of food as prey $type_i$	unitless	Plants - 0	Insectivorous diet
			Invertebrates - 1	

Equation (c) - CPEC intake from ingested soil

$$Intake_{soil} = AUF * (FIR * P_s * C_{js} * AF_{js})$$

Parameters - Equation (c):

Parameter	Description	Units	Value	Source/Notes
$Intake_{soil}$	Intake for contaminant (j) in soil	mg dw/kg bw-d	calculated	
C_{js}	Concentration of contaminant (j) in soil (s)	mg/kg dw	available data	All available site-wide sample data
FIR	Food intake rate	kg dw/kg bw-d	0.207	WDOE 2012 - food ingestion rate for American Robin
P_s	Proportion of total mass intake that is soil	kg soil/kg food	16.4%	EPA 2005 - 90th percentile value for avian insectivore[1]
AF_{js}	Bioavailability factor of contaminant (j) in soil	unitless	1	Bioavailability of copper from ingested food was conservatively assumed to be 100%.[2]
AUF	Area use factor	unitless	1	Fraction of food derived from site; area use assumed to be 100%

Notes:

1 - American woodcock is surrogate species for avian insectivore.

2- The assimilation efficiency or bioavailability of copper in ingested soils or biota was conservatively assumed to be 100%. This is a conservative estimate since the bioavailability of most metals is less, especially directly from incidentally ingested soils or soils in gut content of prey items.

mg - milligram dw - dry weight
kg - kilogram bw - body weight
d - day

Sources:

Bechtel-Jacobs. 1998. Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants. Bechtel-Jacobs Company LLC, Oak Ridge, TN. BJC/OR-133.

Sample B.E., J.J. Beauchamp, R.A. Efroymson, G.W. Suter, II, and T.L. Ashwood. 1999. Literature-derived bioaccumulation models for earthworms: development and validation. Environmental Toxicology and Chemistry 18: 2110-2120.

United States Environmental Protection Agency (EPA). 1993. Wildlife Exposure Factors Handbook. EPA/600/R-93/1987a. Volumes I & II.

United States Environmental Protection Agency (EPA). 2005. Attachment 4-1, Guidance for Developing Ecological Soil-Screening Levels (Eco-SSLs), OSWER Directive 9285.7-55 (issued November 2003, revised February 2005).

Washington State Department of Ecology (WDOE). 2012. Table 749-4: Wildlife Exposure Model for SIte-Specific Evaluations Available at: http://www.ecy.wa.gov/programs/tcp/policies/terrestrial/table_749-4.pdf Taken from: Table Terrestrial Ecological Evaluation (TEE) Process- The Site-Specific Evaluation. Available at: http://www.ecy.wa.gov/programs/tcp/policies/terrestrial/site-specific.htm. Toxics Cleanup Program, Model Toxics Control Act Cleanup (MTCA) Regulation. Accessed 6/22/2012.

Table 5. Ecological Benchmark Values (EBVs) - Birds

Swan Island OU2 Upland Facility Riverbank Soils

Modeled Receptor: American Robin

Analyte	Ecological Benchmark Value	Units	Type of Value	Source/Notes
Copper	4.05	mg dw/kg bw-d	Rep/Gro/Mor NOAEL	"Highest bounded NOAEL, lower than lowest bounded LOAEL for reproduction, growth, or survival" (Figure 5-1 in EPA 2007)
	12.1		LOAEL	LOAEL cited by Oregon DEQ (2013) in comments on SIUF OU2 Level II ERA (Formation Environmental 2012).
	18.5		Rep/Gro NOAEL	"Geometric mean of NOAELs for reproduction and growth" (Figure 5-1 in EPA 2007)
	20.8		Rep/Gro NOAEL	Geometric mean of NOAELs for reproduction/growth endpoints from studies of food consumption exposure over long duration (at least 10 weeks) (from Table 5-1 EPA 2007)
	22		Mor NOAEL	Geometric mean of NOAELs for mortality endpoint from studies of food consumption with an exposure duration of 4 weeks or more (from Table 5-1 EPA 2007)
	28.7		Rep/Gro LOAEL	Geometric mean of LOAELs for reproduction/growth endpoints from studies of food consumption exposure over long duration (at least 10 weeks) (from Table 5-1 EPA 2007)
	42		Mor LOAEL	Geometric mean of LOAELs for mortality endpoint from studies of food consumption with an exposure duration of 4 weeks or more (from Table 5-1 EPA 2007)
	68.4		Mor LOAEL	Mehring et al. 1960 - LOAEL mortality dose calculated from highest dose in study (1180 mg/Kg; food exposure duration for at least 10 weeks; copper oxide consumption by chicks), which resulted in 40% mortality. The dose was calculated using food ingestion rate and body weight information from EPA (2007).

Notes:
EBV = Ecological Benchmark Value
mg dw/kg bw-d = milligrams of dry weight per kilogram of body weight per day
LOAEL = Lowest Observed Adverse Effects Level
NOAEL = No Observed Adverse Effects Level
Rep/Gro = Reproductive/Growth
Mor = Mortality

Sources:

DEQ (Oregon Department of Environmental Quality). 2012. Letter from David Lacey (DEQ) to Dwight Leisle (Port) re: DEQ review of "Level II Screening Ecological Risk Assessment OU2". July 17, 2013.

Formation (Formation Environmental, LLC). 2012. Level II Screening Ecological Risk Assessment (ERA) Portland Shipyard, Operable Unit 2 (OU2), Swan Island Upland Facility (SIUF). Prepared for Ash Creek Associates and the Port of Portland. September.

Mehring, A.L., Jr., J.H. Brumbaugh, A.J. Sutherland, H.W. Titus. 1960. The tolerance of growing chickens for dietary copper. Poultry Science 39: 713-719.

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United States Environmental Protection Agency (EPA). 2007b. Ecological Soil Screening Levels for Copper, Interim Final. OSWER Directive 9285.7-68 (Issued July 2006; Revised February 2007).

Table 6. Avian Population-level Probabilistic Risk Analyses for Copper: Baseline Conditions (discrete samples)

Swan Island OU2 Upland Facility

Analysis of probability of exposure exceeding Acceptable Risk Levels

RECEPTOR: AMERICAN ROBIN - 100% Invertebrate Diet

Exposure Parameters	Value	Unit
IRsoil	0.164	kg soil/kg food
IRfood	0.207	kg dw/kg bw-d
Pplant	0	fraction
Pearthworm	1	fraction
Soil bioavailability factor	1	unitless

CHEMICAL: **Copper** **Discrete samples only**

LOCATION	Concentration of Chemical in Soil		Dose of Chemical	
	Csoil (mg/kg)	ln(Csoil)	Dose (mg/kg BW/day)	ln(dose)
RB-9a	298.00	5.70	41.88	3.73
RB-12b	42.40	3.75	5.96	1.78
RB-11a	57.20	4.05	8.04	2.08
RB-14a	46.70	3.84	6.56	1.88
RB-13b	567.00	6.34	79.69	4.38
RB-9b	284.00	5.65	39.92	3.69
RB-10b	1640.00	7.40	230.51	5.44
RB-11b	125.00	4.83	17.57	2.87
RB-10a	112.00	4.72	15.74	2.76
RB-13a	25.80	3.25	3.63	1.29
RB-15a	50.70	3.93	7.13	1.96
RB-15b	103.00	4.63	14.48	2.67
RB-8b	60.10	4.10	8.45	2.13
RB-8a	112.00	4.72	15.74	2.76
RB-12a	61.40	4.12	8.63	2.16
RB-14b	62.50	4.14	8.78	2.17

STATISTICS				
	mg/kg	ln	mg/kg BW/day	ln
Average	228.0	4.70	32.0	2.73
Standard Deviation	401.8	1.09	56.5	1.09
Distribution			log normal	

PROBABILISTIC ANALYSIS - log based calculations				
Number of animals (n)		22		
EBV (mg/kg/day)	**ln(EBV)**	**Individual Probability of Exp>EBV (p)**	**Probability that more than 20% of the local population will experience Exp>EBV (b)**	**where b=1-BINOMDIST(#kills,#trials,prob of kill,cumulative)**
4.05	1.40	0.891	1.00	**Acceptable Risk Level (ARL) for non T/E Species: probability <0.1**
12.1	2.49	0.588	1.00	
18.5	2.92	0.433	0.99	
20.8	3.03	0.391	0.97	
22.0	3.09	0.371	0.95	
28.7	3.36	0.283	0.79	
42	3.74	0.178	0.35	
68.4	4.23	0.085	0.03	

Notes:

- Refer to Table 2 for description of all exposure parameters and intake/dose equations.
- Refer to Table 3 for description of all ecological benchmark values (EBV).
- All locations are within the riverbank area of Swan Island OU2 Upland Facility; analysis assumes even distribution across riverbank area.
- Method Source: Oregon Department of Environmental Quality (DEQ). 2001. Guidance for Ecological Risk Assessment: Levels I, II, III, IV. Waste Management & Cleanup Division, Final. April 1998, updated December 2001.
- Acceptable risk level (ARL)[OAR 340-122-115(6)] for populations of ecological receptors is a 10% or less chance that 20% or more of the total local population would receive an exposure greater than the EBV.

Table 7. Avian Population-level Probabilistic Risk Analyses for Copper: Effect of Source Control Action (discrete samples)

Swan Island OU2 Upland Facility

Analysis of probability of exposure exceeding Acceptable Risk Levels

RECEPTOR: AMERICAN ROBIN - 100% Invertebrate Diet

Exposure Parameters	Value	Unit
IRsoil	0.164	kg soil/kg food
IRfood	0.207	kg dw/kg bw-d
Pplant	0	fraction
Pearthworm	1	fraction
Soil bioavailability factor	1	unitless

CHEMICAL: **Copper** **Discrete samples only**

LOCATION	Concentration of Chemical in Soil		Dose of Chemical	
	Csoil (mg/kg)	ln(Csoil)	Dose (mg/kg BW/day)	ln(dose)
RB-9a	34.00	3.53	4.78	1.56
RB-12b	42.40	3.75	5.96	1.78
RB-11a	57.20	4.05	8.04	2.08
RB-14a	46.70	3.84	6.56	1.88
RB-13b	567.00	6.34	79.69	4.38
RB-9b	34.00	3.53	4.78	1.56
RB-10b	34.00	3.53	4.78	1.56
RB-11b	125.00	4.83	17.57	2.87
RB-10a	34.00	3.53	4.78	1.56
RB-13a	25.80	3.25	3.63	1.29
RB-15a	50.70	3.93	7.13	1.96
RB-15b	103.00	4.63	14.48	2.67
RB-8b	60.10	4.10	8.45	2.13
RB-8a	112.00	4.72	15.74	2.76
RB-12a	61.40	4.12	8.63	2.16
RB-14b	62.50	4.14	8.78	2.17

STATISTICS				
	mg/kg	ln	mg/kg BW/day	ln
Average	90.6	4.11	12.7	2.15
Standard Deviation	130.5	0.75	18.3	0.75
Distribution			log normal	

PROBABILISTIC ANALYSIS - log based calculations				
Number of animals (n)	22			
EBV (mg/kg/day)	ln(EBV)	Individual Probability of Exp>EBV (p)	Probability that more than 20% of the local population will experience Exp>EBV (b)	where b=1-BINOMDIST(#kills,#trials,prob of kill,cumulative)
4.05	1.40	0.841	1.00	Acceptable Risk Level (ARL) for non T/E Species: probability <0.1
12.1	2.49	0.324	0.89	
18.5	2.92	0.153	0.24	
20.8	3.03	0.120	0.11	
22.0	3.09	0.105	0.07	
28.7	3.36	0.054	5.7E-03	
42	3.74	0.017	3.2E-05	
68.4	4.23	0.003	5.0E-09	

Notes:

- Refer to Table 2 for description of all exposure parameters and intake/dose equations.
- Refer to Table 3 for description of all ecological benchmark values (EBV).
- All locations are within the riverbank area of Swan Island OU2 Upland Facility; analysis assumes even distribution across riverbank area.
- Yellow highlighted values are locations that will be covered as a result of the source control action; values were replaced with the background concentration for copper (34 mg/kg).
- Method Source: Oregon Department of Environmental Quality (DEQ). 2001. Guidance for Ecological Risk Assessment: Levels I, II, III, IV. Waste Management & Cleanup Division, Final. April 1998, updated December 2001.
- Acceptable risk level (ARL)[OAR 340-122-115(6)] for populations of ecological receptors is a 10% or less chance that 20% or more of the total local population would receive an exposure greater than the EBV.

Table 8. Approach for Calculation of Estimated CPEC Intake for Modeled Receptor - Small
Swan Island OU2 Upland Facility Riverbank Soils

Modeled Receptor: Short-Tailed Shrew

Intake Equations:

Equation (a) - total CPEC intake

$$Intake_{total} = Intake_{food} + Intake_{water} + Intake_{soil}$$

Parameters - Equation (a):

Parameter	Description	Units	Value	Source/Notes
$Intake_{food}$	average daily intake from ingestion of prey items (vegetation and animal tissues).	mg/kg	calculated	See Equation (b)
$Intake_{soil}$	average daily intake from incidental ingestion of surface soil.	mg/kg	calculated	See Equation (c)
$Intake_{water}$	average daily intake from the ingestion of water.	mg/kg	0	No surface water at Upland Facility; water intake assumed to be 0.

Equation (b) - CPEC intake from food

$$Intake_{food} = AUF * \left(\sum_{i=1}^{N} B_{ij} * P_i * FIR \right)$$

Parameters - Equation (b):

Parameter	Description	Units	Value	Source/Notes
$Intake_{food}$	Intake for contaminant (j) in food	mg dw/kg bw-d	calculated	
AUF	Area use factor	unitless	1	Fraction of food derived from site; area use assumed to be 100%
FIR	Food intake rate	kg dw/kg bw-d	0.209	EPA 2005 - food ingestion rate for shrew
B_{ij}	Concentration of contaminant (j) in biota type (i) where $\ln(B_{ij}) = Intercept_{ij}+Slope_{ij}*\ln(Soil_j)$	mg/kg dw	$\ln(B_{plants})=(0.394*\ln(Soil_j))+0.668$ $B_{Inverts}=0.515*Soil_j$	Uptake equations from Table 4a in EPA 2005 (based on Bechtel-Jacobs 1998, Sample et al. 1999, etc.)
N	total number of ingested prey types	unitless	1	EPA 2005 - shrew diet
P_i	Fraction of food as prey type$_i$	unitless	Plants - 0 Invertebrates - 1	EPA 2005 - shrew diet

Equation (c) - CPEC intake from ingested soil

$$Intake_{soil} = AUF * (FIR * P_s * C_{js} * AF_{js})$$

Parameters - Equation (c):

Parameter	Description	Units	Value	Source/Notes
$Intake_{soil}$	Intake for contaminant (j) in soil	mg dw/kg bw-d	calculated	
C_{js}	Concentration of contaminant (j) in soil (s)	mg/kg dw	available data	All available site-wide sample data
FIR	Food intake rate	kg dw/kg bw-d	0.209	EPA 2005 - food ingestion rate for shrew
P_s	Proportion of total mass intake that is soil	kg soil/kg food	0.03	EPA 2005 - soil ingestion rate for shrew
AF_{js}	Bioavailability factor of contaminant (j) in soil	unitless	1	Bioavailability of copper from ingested soil and food was conservatively assumed to be 100%.[1]
P_i	Fraction of food as prey type$_i$	unitless	Plants - 0 Invertebrates - 1	EPA 2005 - shrew diet
AUF	Area use factor	unitless	1	Fraction of food derived from site; area use assumed to be 100%

Notes:

1 - The assimilation efficiency or bioavailability of copper in ingested soils or biota was conservatively assumed to be 100%. This is a conservative estimate since the bioavailability of most metals is less, especially directly from incidentally ingested soils or soils in gut content of prey items.

mg - milligram
kg - kilogram
dw - dry weight
bw - body weight
d - day

Sources:

Bechtel-Jacobs. 1998. Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants. Bechtel-Jacobs Company LLC, Oak Ridge, TN. BJC/OR-133.
Sample B.E., J.J. Beauchamp, R.A. Efroymson, G.W. Suter, II, and T.L. Ashwood. 1999. Literature-derived bioaccumulation models for earthworms: development and validation.
United States Environmental Protection Agency (EPA). 2005. Attachment 4-1, Guidance for Developing Ecological Soil-Screening Levels (Eco-SSLs), OSWER Directive 9285.7-55 (issued November 2003, revised February 2005).

Table 9. Ecological Benchmark Values (EBVs) - Small Mammals

Swan Island OU2 Upland Facility Riverbank Soils

Modeled Receptor: Short-Tailed Shrew

Analyte	Ecological Benchmark Value	Units	Type of Value	Source/Notes
Copper	25	mg dw/kg bw-d	NOAEL	Geometric mean of NOAELs for reproduction and growth (EPA 2007)
	45.7		LOAEL	Grobner et al. 1986, as cited in EcoSSL (EPA 2007)
	9.3		LOAEL	LOAEL cited by Oregon DEQ (2013) in comments on SIUF OU2 Level II ERA (Formation Environmental 2012).

Notes:

EcoSSL = Ecological Soil Screening Levels

LOAEL = Lowest Observed Adverse Effects Level

mg dw/kg bw-d = milligrams of dry weight per kilogram of body weight per day

NOAEL = No Observed Adverse Effects Level

Sources:

DEQ (Oregon Department of Environmental Quality). 2012. Letter from David Lacey (DEQ) to Dwight Leisle (Port) re: DEQ review of "Level II Screening Ecological Risk Assessment OU2". July 17, 2013.

Formation (Formation Environmental, LLC). 2012. Level II Screening Ecological Risk Assessment (ERA) Portland Shipyard, Operable Unit 2 (OU2), Swan Island Upland Facility (SIUF). Prepared for Ash Creek Associates and the Port of Portland. September.

Grobner, M. A., Cheeke, P. R., and Patton, N. M. 1986. Effect of dietary copper and oxytetracycline on growth and mortality of weanling rabbits. Journal of Applied Rabbit Research. 9(2): 46-53.

United States Environmental Protection Agency (EPA). 2007. Ecological Soil Screening Levels for Copper, Interim Final. OSWER Directive 9285.7-68 (Issued July 2006; Revised February 2007).

Table 10. Mammalian Population-level Probabilistic Risk Analyses for Copper: Baseline Conditions (discrete samples)

Swan Island OU2 Upland Facility Riverbank Soils

Analysis of probability of exposure exceeding Acceptable Risk Levels

RECEPTOR: Short-Tailed Shrew - 100% Invertebrate Diet

Exposure Parameters	Value	Unit
IRsoil	0.03	kg soil/kg food
IRfood	0.209	kg dw/kg bw-d
Pplant	0	fraction
Pearthworm	1	fraction
Soil bioavailability factor	1	unitless

CHEMICAL: **Copper** **Discrete samples only**

LOCATION	Concentration of Chemical in Soil		Dose of Chemical	
	Csoil (mg/kg)	ln(Csoil)	Dose (mg/kg BW/day)	ln(dose)
RB-9a	298.00	5.70	33.94	3.52
RB-12b	42.40	3.75	4.83	1.57
RB-11a	57.20	4.05	6.52	1.87
RB-14a	46.70	3.84	5.32	1.67
RB-13b	567.00	6.34	64.58	4.17
RB-9b	284.00	5.65	32.35	3.48
RB-10b	1640.00	7.40	186.80	5.23
RB-11b	125.00	4.83	14.24	2.66
RB-10a	112.00	4.72	12.76	2.55
RB-13a	25.80	3.25	2.94	1.08
RB-15a	50.70	3.93	5.77	1.75
RB-15b	103.00	4.63	11.73	2.46
RB-8b	60.10	4.10	6.85	1.92
RB-8a	112.00	4.72	12.76	2.55
RB-12a	61.40	4.12	6.99	1.95
RB-14b	62.50	4.14	7.12	1.96

STATISTICS				
	mg/kg	ln	mg/kg BW/day	ln
Average	228.0	4.70	26.0	2.52
Standard Deviation	401.8	1.09	45.8	1.09
Distribution			log normal	

PROBABILISTIC ANALYSIS - log based calculations				
Number of animals (n)		29		
EBV (mg/kg/day)	ln(EBV)	Individual Probability of Exp>EBV (p)	Probability that more than 20% of the local population will experience Exp>EBV (b)	where b=1-BINOMDIST(#kills,#trials,prob of kill,cumulative)
9.3	2.23	0.607	1.00	Acceptable Risk Level (ARL) for non T/E Species: probability <0.1
25	3.22	0.261	0.81	
45.70	3.82	0.116	0.11	

Notes:

- Refer to Table 6 for description of all exposure parameters and intake/dose equations.
- Refer to Table 7 for description of all ecological benchmark values (EBV).
- Refer to text for description of calculation of number of individuals.
- All locations are within the riverbank area of Swan Island OU2 Upland Facility; analysis assumes even distribution across riverbank area.
- Method Source: Oregon Department of Environmental Quality (DEQ). 2001. Guidance for Ecological Risk Assessment: Levels I, II, III, IV. Waste Management & Cleanup Division, Final. April 1998, updated December 2001.
- Acceptable risk level (ARL)[OAR 340-122-115(6)] for populations of ecological receptors is a 10% or less chance that 20% or more of the total local population would receive an exposure greater than the EBV.

Table 11. Mammalian Population-level Probabilistic Risk Analyses for Copper: Effects of Source Control (discrete samples)

Swan Island OU2 Upland Facility Riverbank Soils

Analysis of probability of exposure exceeding Acceptable Risk Levels

RECEPTOR: Short-Tailed Shrew - 100% Invertebrate Diet

Exposure Parameters	Value	Unit
IRsoil	0.03	kg soil/kg food
IRfood	0.209	kg dw/kg bw-d
Pplant	0	fraction
Pearthworm	1	fraction
Soil bioavailability factor	1	unitless

CHEMICAL: **Copper** **Discrete samples only**

LOCATION	Concentration of Chemical in Soil		Dose of Chemical	
	Csoil (mg/kg)	ln(Csoil)	Dose (mg/kg BW/day)	ln(dose)
RB-9a	34.00	3.53	3.87	1.35
RB-12b	42.40	3.75	4.83	1.57
RB-11a	57.20	4.05	6.52	1.87
RB-14a	46.70	3.84	5.32	1.67
RB-13b	567.00	6.34	64.58	4.17
RB-9b	34.00	3.53	3.87	1.35
RB-10b	34.00	3.53	3.87	1.35
RB-11b	125.00	4.83	14.24	2.66
RB-10a	34.00	3.53	3.87	1.35
RB-13a	25.80	3.25	2.94	1.08
RB-15a	50.70	3.93	5.77	1.75
RB-15b	103.00	4.63	11.73	2.46
RB-8b	60.10	4.10	6.85	1.92
RB-8a	112.00	4.72	12.76	2.55
RB-12a	61.40	4.12	6.99	1.95
RB-14b	62.50	4.14	7.12	1.96

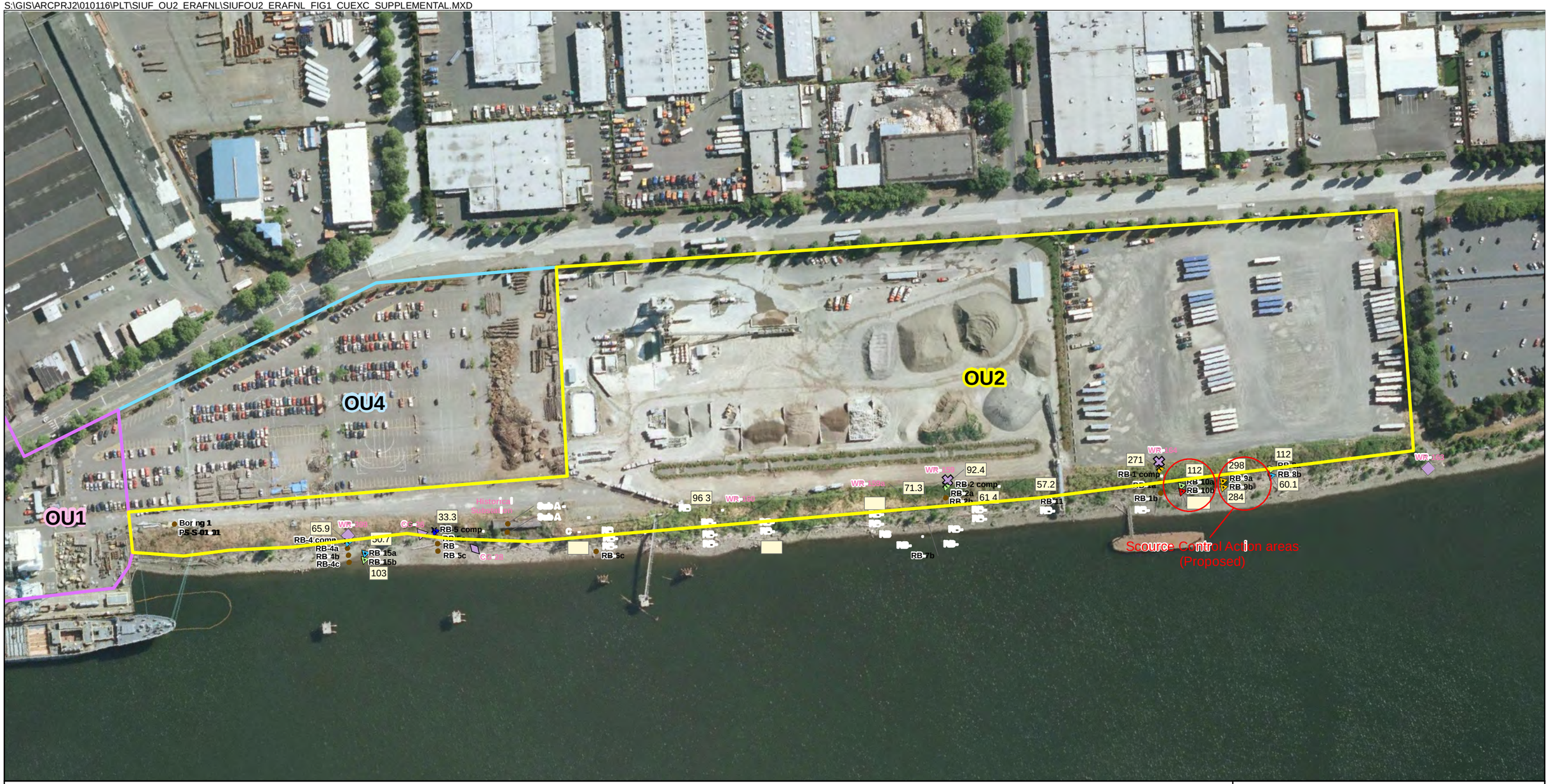
STATISTICS				
	mg/kg	ln	mg/kg BW/day	ln
Average	90.6	4.11	10.3	1.94
Standard Deviation	130.5	0.75	14.9	0.75
Distribution			log normal	

PROBABILISTIC ANALYSIS - log based calculations				
Number of animals (n)	29			
EBV (mg/kg/day)	ln(EBV)	Individual Probability of Exp>EBV (p)	Probability that more than 20% of the local population will experience Exp>EBV (b)	where b=1-BINOMDIST(#kills,#trials,prob of kill,cumulative)
9.3	2.23	0.350	0.97	Acceptable Risk Level (ARL) for non T/E Species: probability <0.1
17.25	2.85	0.113	0.10	
25	3.22	0.044	0.00	
45.70	3.82	0.006	0.00	

Notes:

- Refer to Table 6 for description of all exposure parameters and intake/dose equations.
- Refer to Table 7 for description of all ecological benchmark values (EBV).
- Refer to text for description of calculation of number of individuals.
- All locations are within the riverbank area of Swan Island OU2 Upland Facility; analysis assumes even distribution across riverbank ar
- Yellow highlighted values are locations that will be covered as a result of the source control action; values were replaced with the background concentration for copper (34 mg/kg).
- Method Source: Oregon Department of Environmental Quality (DEQ). 2001. Guidance for Ecological Risk Assessment: Levels I, II, III, IV. Waste Management & Cleanup Division, Final. April 1998, updated December 2001.
- Acceptable risk level (ARL)[OAR 340-122-115(6)] for populations of ecological receptors is a 10% or less chance that 20% or more of the total local population would receive an exposure greater than the EBV.

S:\GIS\ARCPRJ2\010116\PLT\SIUF_OU2_ERAFNL\SIUFOU2_ERAFNL_FIG1_CUEXC_SUPPLEMENTAL.MXD



Legend

Copper Exceedances (mg/kg)
- <34 (Background)
- 34-70 (Plant Eco SSL - all pH)
- 70-160 (Plant toxicity level for pH>=6)
- 160-700 (>Plant SLVs)
- >700 (Hotspot for Plants)
- Other sampling locations

Discrete samples indicated by: ⊙

Composite samples indicated by: +

SIUF OU Boundaries (approx.)
- OU1
- OU2
- OU4

Outfalls/Storm Water Pipes
- Outfall - abandoned
- Outfall - active
- Outfall - inactive
- Storm water pipe (end) - abandoned July 2006

Oregon DEQ-Approved Level II Screening Level Values (SLVs)* - Copper:
Plant (all pH) - 70 mg/kg
Plant (pH>6) - 160 mg/kg
Invertebrate - 80 mg/kg
*Background for Portland Basin - 34 mg/kg

Notes:
- OU = Operable Unit; ERA = Ecological risk assessment
- Composite samples were created by combining discrete samples - but these samples are presented as separate points on this figure, so as to be able to present results for those samples.
- Aerial photography - 2009
- Boundaries and sampling locations are approximate; based on latest information provided by Ash Creek Associates.
- Background (bkg) values from Oregon DEQ: Development of Oregon Background Metals Concentrations in Soil. Technical Report. Land Quality Division Cleanup Program. March 2013.

N

Feet
0 100 200

SWAN ISLAND UPLAND FACILITY

OU2 - SUPPLEMENTAL ECOLOGICAL RISK ANALYSIS

FIGURE 1

PLANT AND INVERTEBRATE SCREENING LEVEL EXCEEDANCES - COPPER

PRJ: 007-017	Date: 11/19/2013	
REV: 0	BY: EJS	CHK: MCL

FORMATION ENVIRONMENTAL

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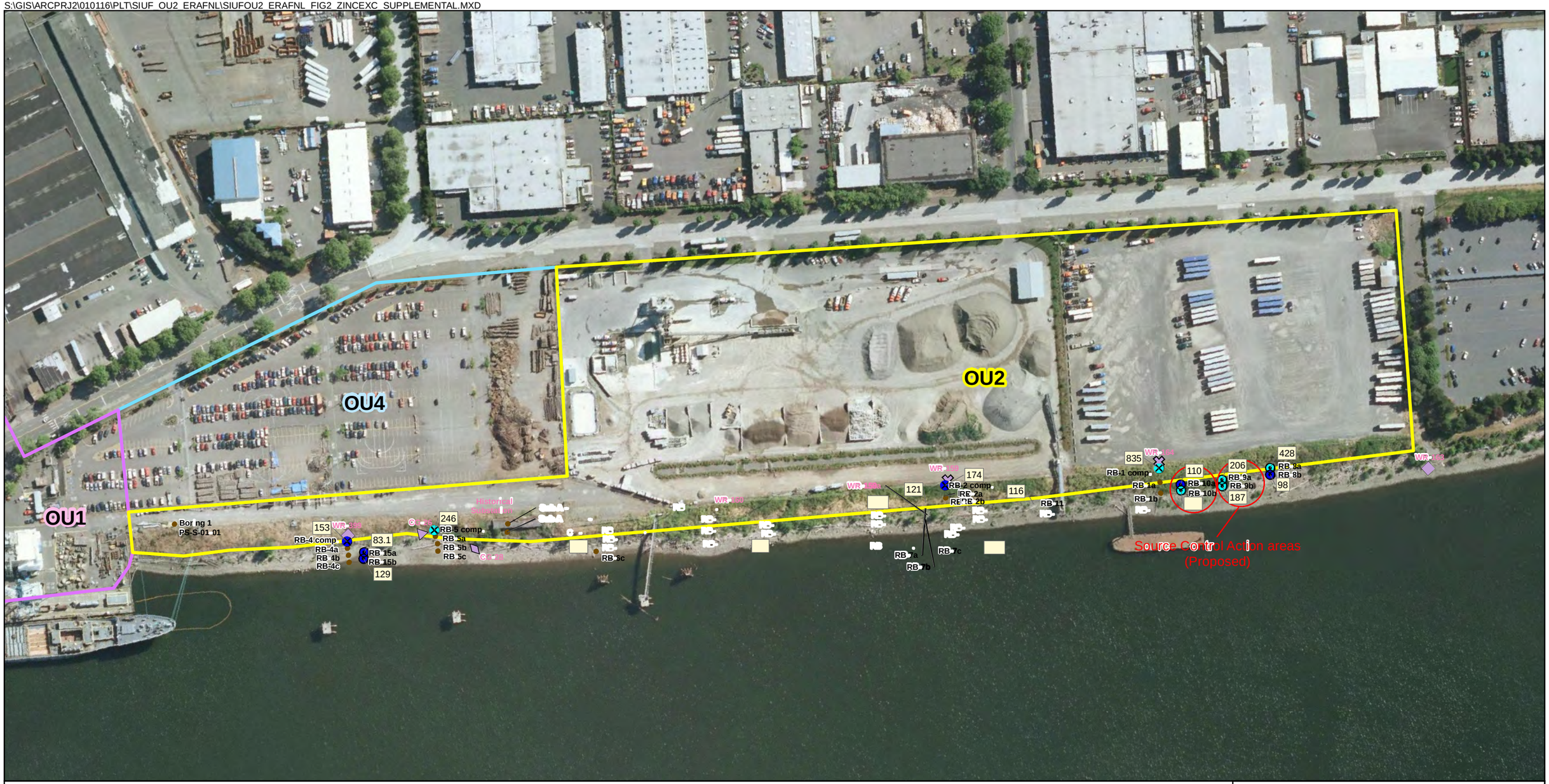

Legend

Zinc Exceedances (mg/kg)
- <180 (Background)
- 180-1200 (>Background and <Hotspots)
- 1200-1600 (Invertebrate Hotspot)
- >1600 (Invertebrate and Plant Hotspot)
- Other sampling locations

Discrete samples indicated by: ⊙

Composite samples indicated by: +

SIUF OU Boundaries (approx.)
- OU1
- OU2
- OU4

Outfalls/Storm Water Pipes
- Outfall - abandoned
- Outfall - active
- Outfall - inactive
- Storm water pipe (end) - abandoned July 2006

Oregon DEQ-Approved Level II Screening Level Values (SLVs)* - Zinc:
Plant - 180mg/kg
Invertebrate - 120 mg/kg
*Background for Portland Basin - 180 mg/kg

Notes:
- OU = Operable Unit; ERA = Ecological risk assessment
- Composite samples were created by combining discrete samples - but these samples are presented as separate points on this figure, so as to be able to present results for those samples.
- Aerial photography - 2009
- Boundaries and sampling locations are approximate; based on latest information provided by Ash Creek Associates.
- Background (bkg) values from Oregon DEQ: Development of Oregon Background Metals Concentrations in Soil. Technical Report. Land Quality Division Cleanup Program. March 2013.

Feet
0 100 200

SWAN ISLAND UPLAND FACILITY

OU2 - SUPPLEMENTAL ECOLOGICAL RISK ANALYSIS

FIGURE 2

PLANT AND INVERTEBRATE SCREENING LEVEL EXCEEDANCES - ZINC

PRJ: 007-017	Date: 11/19/2013	
REV: 0	BY: EJS	CHK: MCL

FORMATION ENVIRONMENTAL

Attachment A

Oregon
John A. Kitzhaber, MD, Governor

Department of Environmental Quality
Northwest Region Portland Office
2020 SW 4th Avenue, Suite 400
Portland, OR 97201-4987
(503) 229-5263
FAX (503) 229-6945
TTY (503) 229-5471

June 17, 2013

Dwight Leisle, Environmental Project Manager
Port of Portland
P.O. Box 3529
Portland, OR 97208

Re: DEQ Review "Level II Screening Ecological Risk Assessment OU2"
ECSI No. 271

Dear Mr. Leisle:

The Department of Environmental Quality (DEQ) reviewed the September 2012 *Level II Screening Ecological Risk Assessment Portland Shipyard, Operable Unit 2 Swan Island Upland Facility*, prepared for the Port of Portland by Formation Environmental.

The risk assessment provides an excellent evaluation of the risk under varying exposure concentrations, toxicity assumptions, and exposure probabilities. DEQ concludes that copper appears to be the driver of terrestrial risk in the riverbank. Copper concentrations are widespread and generally co-located with elevations of other metals such as zinc and lead. However, the largest contribution to unacceptable risk for copper is at RB-10b (1680 mg/kg) and at RB-1 (271 mg/kg). These samples were collected from the riverbank adjacent to the Daimler Area where elevated concentrations of metals have previously been observed. Elevated levels observed in these riverbank samples are likely associated with the historical upland activities in the Daimler Area.

This same area exceeds Joint Source Control Strategies (JSCS) Screening Level Values (SLVs) for several COIs. The source control measure proposed in the November 21, 2012 *Source Control Alternatives Evaluation, Operable Unit 2 Swan Island Upland Facility* is a cap over the areas with the highest metals concentrations. DEQ anticipates that additional action is likely not needed to address ecological risk at the site. DEQ's review comments are provided below. Based on our previous communications a response to these comments is not needed however, they should be incorporated into future risk assessments by the Port as appropriate.

Comments

1. Section 3.2.2, Plant and Invertebrate Screening: The 5x multiplier is used in DEQ guidance to estimate a lowest observed effect level (LOAEL) from a no observed effect level (NOAEL) which can be used as a screen where population level impacts are assessed. However, the multiplier should not be applied to other toxicity benchmarks, such as maximum acceptable toxicant concentrations (MATC) for plants and

invertebrates. Risk estimates should be made to exceedances of the SLVS excluding the 5x multiplier. This identifies lead and arsenic as additional COPCs for plant exposure.

2. Section 4.0, Expanded Assessment, Mammals: Although mammalian SLVs were exceeded during the preliminary risk evaluation, additional expanded analysis was not provided. Copper and zinc were also identified as COPCs for mammalian receptors with risk ratios of 33.47 and 10.57, respectively. An assumption was made in the risk assessment that birds would cover mammalian exposure and toxicity. DEQ evaluated mammalian risk using an expanded assessment and the results are provided below.

3. Table 4-1, American Robin: The bioavailability factors should be set at 1.0. There is no testing information on site soil to show that lead bioavailability is 0.5. Section 3.2.2, and Appendix E-1, PCBs: The historical substation A was screened separately in Appendix E for PCBs while the rest of the data is presented in Appendix C-1 for the Riverbank Summary. It is unclear why this was done as there are only two samples available for the historical substation and these are all considered riverbank samples. For the riverbank in general, it appears from the dataset that there may be a PCB Aroclor 1254 source (613 ug/kg) at RB-10b, labeled as "Area L: Erosion Scarp." This concentration is above the screening level for mammals (SLV = 371 ug/kg) and comparable to the screening level for birds (SLV = 655 ug/kg). However, the rest of the PCB data appear to be below risk-based screening levels.

4. Section 5.1, Population Level Exposure Analysis:

   - Local Population: The population assessed should be the local population as defined by the nature (habitat present) and size of the locality of the facility. The number of organisms in the local population should be based on the number of expected animals within this area. From the information provided, this is 5.54 acres of riverbank habitat. The number of robins expected to occupy 5.54 acres (2.2 hectares) is 22 (5 pairs / hectare – mean, EPA Exposure Factors Handbook). The reduction to 22 from 49 will increase the probability of exposure slightly. However, the assumption of 22 robins in the local population is still likely a high estimate given the linearity and current quality of the habitat. Since high estimates are less conservative within the probability analysis (the more animals the lower the probability of exposure), this is a reasonable assumption and implies some offsite use.

   - Data Distribution: If the data are determined to be normally distributed a natural log transformation is not appropriate. For example, lead composite dose samples are normally distributed but were analyzed using a log transformation. The use of a normal distribution changes the results of the risk analysis.

5. Section 5.2 and Appendix F, Probability of Exposure Risk Analysis: DEQ's definition of acceptable risk for populations of ecological receptors is defined in two parts:

   - A 10 percent chance, or less, that more than 20 percent of the total local population will be exposed to an exposure point value greater than the ecological benchmark value (LD50) for each contaminant of concern.

- No other observed adverse effects on the health or viability of the local population. This evaluation must evaluate effects on reproduction related to fecundity and the sustainability of the local population.

By evaluating probability of exposure to no observed and lowest observed effect levels on mortality, growth and reproduction, the two criteria were met.

6. Section 5.2, Results Summary for Zinc: These results were calculated assuming 22 robins in the locality of the facility and a bioavailability factor for lead of 1.

   - For discrete samples, the results of the exposure probability analysis are unacceptable to birds if the toxicity reference value (TRV) selected is < 144.8 mg/kg/day.

   - For composite samples, the results of the exposure probability analysis is unacceptable to birds if the TRV selected is < 131 mg/kg/day

   This indicates the discrete samples show more risk than the composite samples. As indicated on Page 25, a TRV was reported with a 43% mortality of 87.1 mg/kg/day. DEQ's analysis of EPA 2007 acceptable TRVs as the geometric mean of TRVs for growth and reproduction was 171 mg/kg/day. Therefore, while the ecological benchmark value (EBV) of 271 mg/kg/day is likely too high to be protective of all endpoints, the selection of a TRV of 171 mg/kg/day also results in acceptable risk.

   DEQ concurs with the conclusion of no unacceptable risk for zinc to birds.

7. Section 5.2, Results Summary for Lead, Birds: These results were calculated assuming 22 robins in the locality of the facility and a bioavailability factor for lead of 1.

   - For discrete samples, the results of the exposure probability analysis are unacceptable to birds if the TRV selected is < 11.3 mg/kg/day.

   - For composite samples, the results of the exposure probability analysis are unacceptable to birds if the TRV selected is < 10.9 mg/kg/day.

   This shows that both the discrete and composite samples show unacceptable risk if the TRV is lower than about 11 mg/kg/day. DEQ's analysis of LOAEL TRVs from EPA (2007) selected the LOAEL of 3.3 mg/kg/day from the same study as the NOAEL (Edens and Garlich, 1983). However, considering the geometric mean presented here of NOAELs for reproduction and growth is 10.9 mg/kg/day the risk is considered marginal.

8. Section 5.2, Results Summary for Copper: These results were calculated assuming 22 robins in the locality of the facility and a bioavailability factor for lead of 1.

   - For discrete samples, the results of the exposure probability analysis are unacceptable to birds regardless of which TRV is selected. The TRV selected would have to be > 80 mg/kg/day in order to show acceptable risk.

- For composite samples, the results of the exposure probability analysis are unacceptable to birds if the TRV selected is < 28.7 mg/kg/day.

The discrete samples show more risk than the composite samples. DEQ's analysis of EPA (2007) selected the LOAEL of 12.1 mg/kg/day from the same study as EPA's NOAEL (Ankari 1989).

The conclusion is unacceptable risk for bird exposure to copper for discrete samples.

9. Section 6.0, Ecological Risk Assessment Conclusions. DEQ's risk summary is presented below.

Zinc: Risk limited to plants and invertebrates

- Birds: Acceptable risk.
- Mammals: Acceptable risk based on DEQ's expanded assessment.
- Plants and Invertebrates: Unacceptable risk; exceedances appear to be widespread

Lead: Risk of exposure to lead is marginally unacceptable for birds and acceptable for mammals. Plant exposure is above risk levels.

- Birds: Marginal unacceptable risk. For birds, lead risk levels appear to be slightly above or equal to acceptable risk levels. Discrete and composite samples provide virtually the same result.
- Mammals: Acceptable risk. Lead fails at a NOAEL of 4.7 mg/kg/day and a LOAEL of 8.9 mg/kg/day based including growth and reproduction. An expanded assessment shows the TRV selected would have to be lower than 13 mg/kg/day to be unacceptable considering growth and reproduction. Based on an examination of NOAEL and LOAEL studies in EPA 2007 it appears that a TRV>13 is reasonable. Mammalian risk to lead is considered acceptable.
- Plants: Exceeds risk levels.

Copper: Risk of exposure to copper is unacceptable to multiple levels of the ecosystem including birds, mammals, plants and invertebrates. This appears to be the driver of terrestrial risk in the riverbank. This chemical is also a priority for source control.

- Birds: Unacceptable risk.
- Mammals: Unacceptable risk. For mammals, the TRV would have to be 70 mg/kg/day (discrete) to be acceptable, which is significantly higher than DEQ's selected LOAEL of 9.3 mg/kg/day and most mortality LOAELs provided in EPA 2005. Therefore, unacceptable risk is identified to mammals from exposure to copper
- Plants and Invertebrates: Unacceptable risk.

If you have any questions regarding these comments please feel free to contact me at (503) 229-5354.

Sincerely,

David Lacey
Project Manager
Portland Harbor Section

cc: Herb Clough, Ash Creek Associates, Inc.
Michael Pickering, Ash Creek Associates, Inc.
Richard Muza, EPA
Jennifer Peterson, DEQ